U. S. FISH AND WILDLIFE SERVICE
SPECIES ASSESSMENT AND LISTING PRIORITY ASSIGNMENT FORM

SCIENTIFIC NAME: *Lampsilis rafinesqueana*

COMMON NAME: Neosho mucket

LEAD REGION: 4

INFORMATION CURRENT AS OF: March 12, 2010

STATUS/ACTION:

___ Species assessment – determined species did not meet the definition of endangered or threatened under the Act and, therefore, was not elevated to Candidate status

___ New candidate

_X_ Continuing candidate

___Non-petitioned

_X_ Petitioned - Date petition received: _May 11, 2004__

___ 90-day positive - FR date: ___

___ 12-month warranted but precluded - FR date: ___

___ Did the petition request a reclassification of a listed species?

FOR PETITIONED CANDIDATE SPECIES:

a. Is listing warranted (if yes, see summary of threats below)?_yes

b. To date, has publication of a proposal to list been precluded by other higher priority listing actions? _yes

c. If the answer to a. and b. is "yes", provide an explanation of why the action is precluded. Higher priority listing actions, including court-approved settlements, court-ordered and statutory deadlines for petition findings and listing determinations, emergency listing determinations, and responses to litigation, continue to preclude the proposed and final listing rules for the species. We continue to monitor populations and will change its status or implement an emergency listing if necessary. The "Progress on Revising the Lists" section of the current CNOR (*http://endangered.fws.gov/*) provides information on listing actions taken during the last 12 months.

____ Listing priority change

Former LP: __

New LP: __

Date when the species first became a Candidate (as currently defined): 2000

___ Candidate removal: Former LP: ___ (Check only one reason)

___ A – Taxon is more abundant or widespread than previously believed or not subject to the degree of threats sufficient to warrant issuance of a proposed listing or continuance of candidate status.

____U – Taxon not subject to the degree of threats sufficient to warrant issuance of a proposed listing or continuance of candidate status due, in part or totally, to conservation efforts that remove or reduce the threats to the species.

___ F – Range is no longer a U.S. territory.

___ I – Insufficient information exists on biological vulnerability and threats to support listing.

___ M – Taxon mistakenly included in past notice of review.

___ N – Taxon does not meet the Act's definition of "species."
___ X – Taxon believed to be extinct.

ANIMAL/PLANT GROUP AND FAMILY: Clams and Mussels - Unionidae

HISTORICAL STATES/TERRITORIES/COUNTRIES OF OCCURRENCE
Arkansas, Kansas, Oklahoma, Missouri

CURRENT STATES/TERRITORIES/COUNTRIES OF OCCURRENCE:
Arkansas, Kansas, Oklahoma, Missouri

LAND OWNERSHIP
Over 90% of the lands draining the watersheds populated by Neosho mucket are privately owned. An extensive reach (approximately 17 river miles) of the Illinois River in Arkansas flows through the Ozark National Forest – Wedington Ranger District. With the exception of the Spring River, river reaches currently supporting Neosho mucket in Kansas and Oklahoma are controlled or affected by U.S. Army Corps of Engineers Reservoirs. The Oklahoma Department of Wildlife Conservation manages a 565-acre primitive area on the Illinois River. The Nature Conservancy owns four preserves in the watershed totalling approximately 18,000 acres. The Peoria Tribe of Oklahoma is a federally recognized tribe in Ottawa County, Oklahoma. The Tribe's historic jurisdiction encompasses approximately 57 square miles and includes portions of the Spring and Neosho rivers and their tributaries.

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LEAD FIELD OFFICE CONTACT: Arkansas Field Office, Chris Davidson, 501-513-4481. chris_davidson@fws.gov

BIOLOGICAL INFORMATION

<u>Species Description</u>

The Neosho mucket is generally larger than other species of mussels in its habitat. Shiver (2002, pp. 2-3) summarizes the general morphology of the Neosho mucket as follows:

> The shell is oblong, with height about 0.58-0.7 times the length of the shell. The umbones are low and project only slightly or not at all above the dorsal curvature of the shell. Viewed from the side, the dorsal margin is gently rounded and the ventral margin is straight to gently curved. The anterior end is rounded. At the posterior end, the female is relatively taller than the male and inflated in the marsupial area.
>
> The shell is relatively thin and compressed in Shoal Creek specimens, but may be heavy and thick in other rivers, particularly in older specimens. Growth-rest lines are fairly prominent. The epidermis is usually light brown. Young specimens are marked with green, discontinuous rays (chevrons). These markings provide positive identification if present. On the inside of the shell, the left valve has two stout, divergent, striated, triangular pseudocardinal teeth. The two lateral teeth are short, stout, and slightly curved, and the beak cavities are relatively shallow. The nacre is usually bluish-white to white and slightly iridescent towards the posterior.

Taxonomy

A member of the freshwater mussel family Unionidae, the Neosho mucket was originally described as *Lampsilis rafinesqueana* Frierson, 1927. The type locality is Indian Creek, McDonald County, Missouri (Frierson 1927, pp. 69-70). There is no synonomy of the Neosho mucket. The species is currently deemed valid by the Committee on Scientific and Vernacular Names of Mollusks of the Council of Systematic Malacologists and the American Malacological Union (Turgeon *et al*. 1998, p. 35).

Habitat

The Neosho mucket is associated with shallow riffles and runs with gravel substrate and moderate to swift currents (Oesch 1984, p. 221; Obermeyer 2000, pp. 15-16). Channel stability is an important factor determining the location of Neosho muckets. Neosho muckets need substrate loose enough to allow burrowing. Typically individuals are deeply imbedded in the substrate, often with the foot partly extended (Barnhart 2003, p. 17). The species is most often found in areas with swift current, but in Shoal Creek and the Illinois River it prefers near shore areas or areas out of the main current.

Life History

Like most unionid mussels, Neosho mucket is an obligate parasite on fishes as larvae (glochidia). Neosho mucket glochidia transform well on smallmouth and largemouth bass (Barnhart and Roberts 1997, p. 18). Spotted bass, largemouth bass, and smallmouth bass are likely to be a primary host in nature (U.S. Fish and Wildlife Service 2005, p. 7; Barnhart and Roberts 1997, p. 18). The Neosho mucket is unusual among other *Lampsilis* species in the timing of reproduction. Neosho musket spawns in late April and May and broods glochidia from May through August, and females displaying mantle lures have been observed July through September (Shiver 2002, pp. 12-13). Most other *Lampsilis* spawn in the late summer or fall and brood glochidia throughout the winter months into the following spring or summer. The female Neosho mucket extends a pair of mantle flaps (actually an extension of the inner lobe of the mantle edge) that, from a side angle, remarkably resembles a small fish. Each mantle flap in addition to its fish-like shape has pigmentation that resembles an eyespot as well as a fish's lateral line. Muscular contractions of the mantle flaps create an undulating or "swimming" motion that apparently acts as a lure to attract potential fish hosts (Obermeyer 2000, p. 9). Barnhart (2003, p. 9) reported average fecundity to be approximately 1.3 million glochidia per female in the Spring River, Kansas.

Historical and Current Distribution/Status

The Neosho mucket is known only from the Illinois, Neosho, and Verdigris River basins in Arkansas, Kansas, Missouri, and Oklahoma. These basins flow into the Arkansas River in northeastern Oklahoma. The Neosho mucket has been historically reported from the Illinois River in Oklahoma and Arkansas; the Neosho River in Oklahoma and Kansas; Neosho River tributaries including the Elk River in Missouri; Cottonwood River in Kansas; and the Spring River and its tributaries in Oklahoma, Kansas, and Missouri; North Fork Spring River and Indian Creek in Missouri; Shoal and Center Creeks in Missouri; the Verdigris River and its tributaries in Oklahoma and Kansas; Caney River in Oklahoma and Kansas; and Fall River in Kansas (Harris and Gordon 1988, pp. 53-54; Obermeyer *et al*. 1997a, pp. 44-47; Mather 1990, pp. 7-13; Vaughn

1996, pp. 3-5). Survey results and inundation by reservoir construction suggest that the species has been extirpated from the following streams or stream reaches:

Kansas

- Neosho River and tributaries upstream of John Redmond Reservoir (153 river miles)
- Verdigris River upstream of Toronto Lake (57 river miles)
- Fall River and tributaries upstream of Fall River Lake (32 river miles)
- Shoal Creek (6 river miles)
- Caney River (31 river miles)
- Elk River (49 river miles)
- Spring River downstream of Center Creek confluence (15 river miles)

Missouri

- Center Creek (39 river miles)
- Indian Creek (25 river miles)

Oklahoma

- Illinois River downstream of Lake Tenkiller (31 river miles)
- Neosho River (156 river miles)
- Verdigris River (143 river miles)
- Caney River (68 river miles)
- Spring River (19 river miles)
- Elk River (11 river miles)

Arkansas **-** A number of surveys have been conducted to determine the range and status of the Neosho mucket. Gordon *et al.* (1979, pp. 35-36) surveyed 16 sites between Hogeye and Siloam Springs, Arkansas, in the Illinois River circa 1978. They reported Neosho mucket as part of the Mollusca fauna, but did not provide distribution or abundance information on the species. Harris (1991, p. 7) reported five live Neosho mucket from two sites located between Arkansas Highway 59 and the Arkansas/Oklahoma state line. In 1994, the Illinois River was surveyed at two locations, Ozark National Forest (SW ¼ NE ¼ Section 7, T17N, R32W) and Clement's Property (SW ¼ SE ¼ Section 9, T15N, R31W), for the Two Ton Loop Pipeline. Thirteen Neosho mucket specimens were collected at the Ozark National Forest site and one individual was collected from the Muddy Fork Illinois River (Environmental and Gas Consulting, Inc. 1994, field data sheets). This represents the only specimen ever collected from the Muddy Fork Illinois River, and habitat generally is unsuitable for mussel colonization and limited to a couple miles upstream of its confluence with the Illinois River. Harris (1998) conducted a status survey of the Neosho mucket in Arkansas and found it at 19 of 22 survey sites in the Illinois River, Washington and Benton Counties. Although the Neosho mucket was the third most abundant species collected from the approximately 50 kilometer (30 mile) surveyed reach of river, there was little evidence of recent recruitment (*i.e.*, small, young mussels were seldom collected; Harris 1998, p. 5).

No mussel surveys of the Illinois River in Arkansas occurred again until an Arkansas Game and Fish Commission survey of two sites in 2005. Neosho mucket was the third most abundant (76 individuals; 26 percent of total mussel community) mussel at a site upstream of Robinson Road bridge surveyed in June, 2005. Sixteen Neosho mucket were collected at the second site 800 meters downstream of Chambers Spring Road (B. Posey, Arkansas Game and Fish Commission 2005, personal communication (pers. comm.)).

The Arkansas Game and Fish Commission and the U.S. Fish and Wildlife Service (Service) conducted a comprehensive status survey for Neosho mucket in the Arkansas portion of the Illinois River in 2008. Live specimens of Neosho mucket were collected at 9 of 15 survey sites. There was a 32 percent decline in number of survey sites versus the Harris (1998) status survey and a 53 percent decline in the number of sites inhabited by the Neosho mucket. Sixty-seven percent of the sites with Neosho mucket present were represented by three or fewer live individuals. Neosho mucket was the fourth most abundant species in this portion of the river, but three sites accounted for 85 percent of Neosho mucket individuals (52) collected during this survey. Of the 15 survey sites, only two appear stable with the rest in decline and extirpation is imminent. No mussels were collected at the Arkansas Game and Fish Commission 2005 sites during 2008 further documenting the precipitous decline of mussels in the Arkansas portion of the Illinois River. (C. Davidson 2009, pers. comm.). The species has not been found in surveys of other tributaries of the Arkansas River in Arkansas (Harris and Gordon 1988, p. 54).

Oklahoma **-** Living Neosho mucket were found to be locally common in about 92 km (55 mi) of the Illinois River from the Oklahoma - Arkansas state line, downstream to the headwaters of Lake Tenkiller, Cherokee County, Oklahoma (Mather 1990, pp. 7-11). The population within the survey reach was estimated at more than 1,200 individuals. Population demographics were skewed toward older cohorts, and only three animals were encountered during the survey that could be considered juveniles (*i.e*., there was little evidence of recent recruitment). Neosho muckets were not found within or below Lake Tenkiller.

More recent surveys in northeastern Oklahoma (Vaughn 1995, p. 3; 1997, p. 6) found Neosho mucket locally common at 9 of 52 sites on the Illinois River. Vaughn (1997, p. 14) estimated the population within the Oklahoma portion of the Illinois River (the same reach surveyed by Mather in 1990) at between 500 and 1,000 animals. Although some evidence of reproductive potential was observed (*i.e*., gravid females displaying mantle lures), there was little evidence of recruitment into the population (*i.e*., very few small, young Neosho mucket were collected).

Searches in other historically occupied drainages in Oklahoma found no live Neosho mucket at a total of 10 sites in the Spring River, 17 sites in the Neosho River, 32 sites in the Verdigris River, and 29 sites in the Caney River. However, relic Neosho mucket shells confirmed the historic presence of the species at many of these sites, and fresh dead Neosho mucket shells were found at two sites on the Spring River. The results of these recent surveys suggest the Neosho mucket has been extirpated from the Caney, Verdigris, Neosho, and Spring Rivers in Oklahoma (Mather 1990, pp. 16-17; Vaughn 1996, p. 3; 1997, pp. 7-9). Researchers at Oklahoma State University have revisited sites in the Verdigris and Caney Rivers surveyed by Vaughn in the 1990's and confirmed that the species is still extirpated from these rivers in Oklahoma (C. Boeckman 2008, pers. comm.).

Kansas **-** During recent mussel surveys of historically occupied streams in Kansas, living Neosho mucket or fresh dead shells were found in the lower Fall River, Greenwood and Wilson Counties; the Verdigris River between the Toronto Lake Dam and the confluence of the Elk River, Wilson and Montgomery Counties; the Neosho River between the John Redmond Reservoir Dam and the Parsons City Dam in Coffey, Allen, and Neosho Counties; and Spring River in Cherokee County (Obermeyer *et al*. 1997a, pp. 44-46; Obermeyer 2000, pp. 8-9). Neosho mucket was relatively rare in the Fall, Verdigris, and Neosho Rivers, and

Shoal Creek. The Neosho mucket is more abundant in the Fall River than the Verdigris River as evidenced by Obermeyer *et al.* (1995, p. 71). This survey effort documented that Neosho mucket comprised 1.7 percent of the native mussel community in 1994. Most specimens were over 20 years in age.   In 2004, these sites were resurveyed and Neosho mucket composed 1 and 0.05 percent of qualitative and quantitative surveys, respectively. Sample size was small and it is uncertain whether this represents a real decline or sampling error (V. Tabor 2008, pers. comm.).

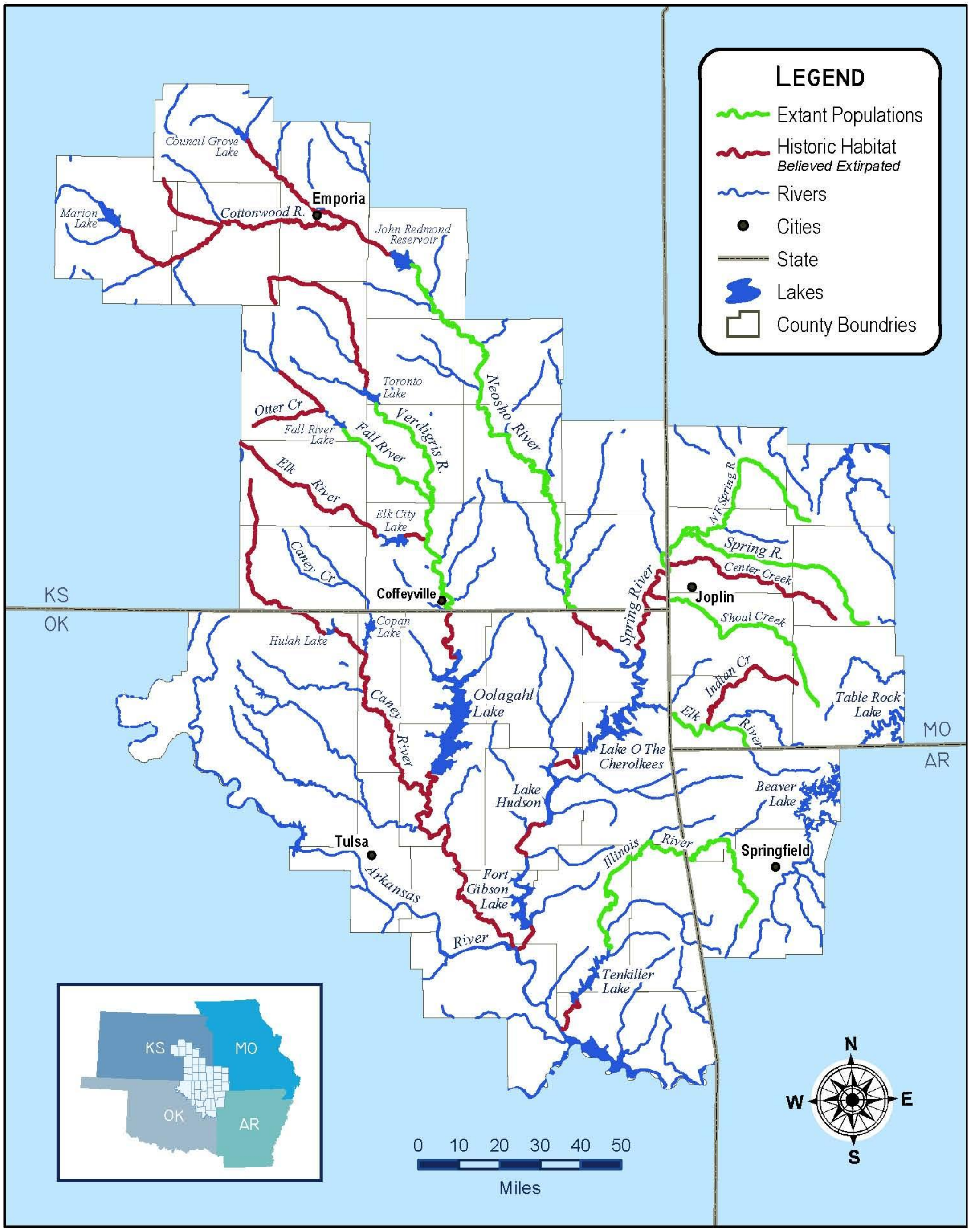
The Neosho mucket occurs in the Verdigris River, but it is seldom found during surveys with the exception of the sites where propagated young have been released. These sites have not been surveyed in several years, but are scheduled for sampling in 2010. A total of 80 square meter quadrats were searched at two Verdigris River sites in 2009 (40 per site). A total of 740 mussels were found within these 80 quadrat samples. Of those, there was one Neosho mucket sampled (length 125mm). This is typical of these two sites as one Neosho mucket was found in 1992, one in 1997, and zero in 2003. However, the total density of other mussel species at both of these sites continues to increase (E. Miller 2010, pers. comm.). Overall relative abundance of Neosho mucket in the Verdigris River ranges from 0.1 to 0.3 percent (V. Tabor 2008, pers. comm.).

Neosho mucket is most abundant in a short reach (approximately 10 km [~6 mi]) of the Spring River, between the Missouri/Kansas state line and the confluence of Center Creek, where it was the most abundant species found at 11 collection sites. At one site surveyed in 2006 there was recent evidence of recruitment; 8 -10 percent of total Neosho muckets collected were less than 5 years old; V. Tabor 2008, pers. comm.)

Missouri **-** During mussel surveys of historically occupied streams in Missouri, living Neosho mucket or fresh dead shells were found in the Spring and North Fork Spring Rivers, and Center and Shoal Creeks in Jasper County (Obermeyer *et al*. 1997a, p. 44). Neosho mucket was relatively rare in the North Fork Spring River and Shoal Creek. The Neosho mucket also is relatively rare in the Elk River, occurring from near Noel, Missouri, to the Missouri/Oklahoma state line. However, there is evidence of brooding females and juveniles from two sites from 1992 to 1998 (C. Barnhart 2008, pers. comm.). The Neosho mucket population in the Spring River appears to be stable at the “main stay” sites (e.g., at Carthage) and there has been successes with stocking juveniles at some of these sites (S. Faiman 2008, pers. comm.). In Center Creek, Jasper County, only a single fresh dead shell was found. At all sites where living Neosho mucket was found, there was little evidence of recruitment.

Summary of Status - It is difficult to adequately determine and describe the temporal decline of Neosho mucket since most surveys have occurred during the past 15 years (see threats section below). The Neosho mucket has been extirpated from approximately 62 percent (835 river miles (1334 river kilometers) of its historic range and is in imminent danger of being extirpated from the Arkansas portion of the Illinois River (30 river miles)(48 river kilometers). Most of this extirpation has occurred within the Oklahoma and Kansas portions of its range. While once the third most abundant

Figure 1. Historic and currently occupied habitat for the Neosho mucket in AR, KS, MO, and OK.



mussel species in the Arkansas portion of the Illinois River, the rapid collapse since 2005 of the entire mussel community in this river segment is particularly alarming and represents a 50 percent decline in viable stream populations. Extant populations still exist in 508 river miles (818 river kilometers) within the historic range.

The Neosho mucket survives in four river drainages, however, only one of these, the Spring River, currently supports a potentially viable population of the species due to the presence of a relatively large number of individuals. However, recruitment is either very low or not occurring in all of the extant populations. One-week old juveniles have been released in the Fall River (32,150 juveniles), Verdigris River in Kansas (88,900 juveniles), Shoal Creek in Missouri (142,400 juveniles), and Spring River in Kansas and Missouri (1,072,110 juveniles) between 1999 and 2004 (C. Barnhart 2005, pers. comm.). Approximately 200,000 juveniles were released at two locations near Peoria, Oklahoma on Peoria Tribal lands in 2007. Fifty-seven tagged juveniles were released at a Spring River site near Carthage, Missouri in 2007 (S. Faiman 2008, pers. comm.).

Documenting survival of released juveniles has been difficult due to the size of individuals released and their ability to remain at the release site and not be washed downstream prior to becoming established at release sites. Less than 100 juveniles have been recaptured from the Fall and Verdigris Rivers and only one individual has been recaptured from the Neosho River near the Peoria Tribe lands (C. Barnhart, pers. comm., 2009). Our ability to better assess juvenile survivorship should be much improved due to recent advancements in juvenile rearing techniques at the Kansas City Zoo and Missouri State University. Researchers and managers now have the ability to grow Neosho mucket juveniles to one year of age, which allows marking of individuals and placement in suitable substrate, versus releasing two week old juveniles in previous efforts where marking and placement was not an option (C. Barnhart 2009, pers. comm.).

THREATS

A. <u>The present or threatened destruction, modification, or curtailment of its habitat or range</u>.

The reduction of habitat and range of the Neosho mucket has been attributed to impoundment, sedimentation, agricultural pollutants and lead and zinc mining (Mather 1990, pp. 18-19; Obermeyer *et al*. 1997b, pp 113-115). At least 11 major dams have been constructed that have impounded significant portions of the historic range of the Neosho mucket, effectively resulting in fragmented populations and habitats. There is currently discussion regarding a proposed reservoir on Shoal Creek, Missouri, to provide water to Springfield and Joplin. This proposed reservoir has not been funded or approved as of this time (A. Roberts 2009, pers. comm.). The species does not tolerate impounded conditions, and has not been collected from impounded portions of its historic habitat. In addition, it is believed that the operation of these dams will continue to negatively affect the Neosho mucket. For instance, Obermeyer *et al*. (1997b, p. 114) noted extensive bank scouring in the Neosho River below John Redmond Dam and made observations that suggest channel instability as a primary factor limiting mussel distribution below this dam.

Several types of pollutants are thought to affect Neosho mucket populations. Sediment is probably the most abundant pollutant currently affecting the Neosho mucket (Obermeyer 2000, p. 9). Sediment sources within the current range of the Neosho mucket include historical mining activity; cultivated fields; cattle grazing; and urban, suburban, and rural construction activities. Excessive sedimentation is known to cause direct mortality of freshwater mussels by deposition and suffocation (Ellis 1936, pp. 29-42) and can eliminate or reduce the recruitment of juvenile mussels (Negus 1966, pp. 513-532; Brim-Box and Mossa 1999, pp. 99-102). High suspended sediment levels can also interfere with feeding activity (Dennis 1984, summary of 171 page dissertation). Sediment levels within the range of the Neosho mucket are higher than historic levels and are likely to increase. For example, the Illinois River in Arkansas drains portions of the two fastest growing counties in Arkansas (U.S. Census Bureau, www.factfinder.census.gov). Continued development and growth within this basin will likely result in increased sediment impacts to this river and to the Neosho mucket population found there.

Channel instability emerged in 2008 as the primary threat to not only the Neosho mucket population but an entire mussel community in the Arkansas portion of the Illinois River. Channel instability in this segment of the Illinois River can be attributed to two sources: 1) urban development in the watershed resulting in altered river hydrology and geomorphology (i.e., more frequent flood events that alter channel characteristics), and 2) clearing of riparian vegetation for conversion to pasture (i.e., increase in number and length of eroding stream banks). This segment of the Illinois River is aggrading (building up in level or slope through sediment deposition) in areas that previously supported large mussel concentrations, which leaves previously suitable habitat exposed to dry conditions during most of the year. The river completely abandoned historic channels that supported Neosho mucket during 2008 flood events, which was exacerbated by urban development and clearing of forested riparian habitat in the watershed (C. Davidson 2009, pers. comm.).

Nutrients, usually phosphorus and nitrogen, can emanate from agricultural, urban, and suburban runoff, including cultivated fields and pastures, livestock feedlots, leaking septic tanks, residential lawns, etc., at levels that result in eutrophication and reduced oxygen levels. Eutrophication, caused by the introduction of excess nutrients to a water body, has been shown to result in periodic low dissolved oxygen levels that are detrimental to mussels (Sparks and Strayer 1998, pp. 131-133). Excess nutrients also promote heavy growth of blue-green and other algae that can eliminate habitat for juvenile mussels. Extirpation of mussel species including the Neosho mucket from the Cottonwood River during the 1960's was attributed to feedlot runoff, and the Joplin wastewater treatment plant also has been implicated as causing mussel declines in Shoal Creek (Obermeyer *et al*. 1997b, p. 114). The upper Arkansas basin is a center for poultry production, and nutrification from spreading of poultry waste on pastureland is an increasing problem (i.e., Illinois River and Elk River, Missouri). The Elk River basin accounts for the second largest concentration of poultry in Missouri (approximately 6 million broilers and other meat-type chickens; Smith *et al.* 2007, p. 50). Nutrient concentrations, including ammonia in sediment samples, have increased significantly since the 1960s in the Elk River basin. Concentrations in the 1970s and 1980s, though similar, had increased from those in the 1960s, and the concentrations from the 1990s and 2000s increased still more (Smith *et al.* 2007, pp. 50-51).

Butler (2005, pp. 101-107) summarized the effects of contaminants on mussels in part as follows:

> *The effects of contaminants (e.g., metals, chlorine, ammonia) are especially profound on juvenile mussels (Robison et al. 1996, Jacobson et al. 1993, Bartsch et al. 2003, Mummert et al. 2003), which can readily ingest contaminants adsorbed to sediment*

particles while feeding (Newton 2003), and on the glochidia, which appear to be very sensitive to toxins (Goudreau et al. 1993, Jacobson et al. 1997). Mussels are very intolerant of heavy metals (Keller and Zam 1991, Havlik and Marking 1987), and even at low levels, certain heavy metals may inhibit glochidial attachment to fish hosts (Huebner and Pynnönen 1992). Cadmium appears to be the heavy metal most toxic to mussels (Havlik and Marking 1987), although chromium, copper, mercury, and zinc also negatively affect biological processes (Wilcove and Bean 1994; Naimo 1995; Keller and Zam 1991; Jacobson et al. 1993, 1997; Keller and Lydy 1997).

Among pollutants, ammonia warrants priority attention for its effects on mussels (Augspurger et al. 2003), and has been shown to be lethal at concentrations of 5.0 parts per million (ppm) (Havlik and Marking 1987). The un-ionized form of ammonia (NH_3) is usually attributed as being the most toxic to aquatic organisms (Mummert et al. 2003), although the ammonium ion form (NH_4^+) may contribute to toxicity under certain conditions (Newton 2003). Documented toxic effects on marine and freshwater mussels include reduction in time valves are held open for respiration and feeding; impaired secretion of the byssal thread; reduced ciliary action impairing feeding; depleted lipid, glycogen, and other carbohydrate stores; altered metabolism; and acute toxicity (Goodreau et al. 1993, Mummert et al. 2003). Sources of ammonia are agricultural (e.g., animal feedlots, nitrogenous fertilizers), municipal (e.g., effluents of out-dated WWTPs), and industrial (e.g., waste products) as well as from precipitation and natural processes (e.g., decomposition of organic nitrogen) (Goodreau et al. 1993, Hickey and Martin 1999, Augspurger et al. 2003, Newton 2003). Atmospheric deposition is one of the most rapidly growing sources of anthropogenic nitrogen entering aquatic ecosystems (Newton 2003) and livestock are the largest global source of atmospheric ammonia (Robarge et al. 2002). Agricultural sources of ammonia may be highly variable over time (Hickey and Martin 1999), compounding the determination of accurate concentration readings.

Toxic effects of ammonia are more pronounced at higher pH and water temperature because the level of the un-ionized form increases as a percentage of total ammonia (Mummert et al. 2003, Newton 2003). Therefore, this contaminant may become more problematic for juvenile mussels during low flow, high temperature periods (Newton et al. 2003). In stream systems, ammonia is frequently at its highest concentrations in interstitial spaces where juvenile mussels live and feed (Whiteman et al. 1996, Hickey and Martin 1999, Augspurger et al. 2003), and may occur at levels that exceed water quality standards (Frazier et al. 1996). Due to its high level of toxicity and the fact that the highest concentrations occur in the microhabitat where mussels live, ammonia should be considered among the factors potentially limiting survival and recovery of mussels at some locations (Augspurger et al. 2003).

Water quality, sediment quality, health of host fish and diet all have the potential to influence survival of mussel life stages and subsequent reproduction and recruitment. Cope *et al.* (in press) evaluate what is currently known about contaminant exposure route, exposure location, exposure duration, and relative sensitivity of each life stage. An emerging concern/threat is waterborne (and potentially sediment) toxicant exposure to chemicals that act directly on the neuroendocrine pathways controlling reproduction, which can cause premature release of viable or nonviable glochidia. The active ingredient in many human prescription anti-depressant drugs belonging to the class of selective serotonin reuptake inhibitors exert reproductive effects on mussels similar to serotonin, making environmental exposures from this class of human pharmaceuticals an imminent threat to native mussel populations (Cope *et al.*, in press). Another study in northwestern Arkansas found pharmaceuticals or other organic wastewater constituents present at all sites (11) surveyed in the Illinois River watershed in 2004 (Galloway *et al.* 2005, pp. 4-22). Pharmaceuticals or organic wastewater constituents were generally greater downstream of wastewater treatment facilities (Galloway *et al.* 2005, p. 28).

Pesticide residues from agricultural, residential, or silvicultural activities commonly end up in streams where the effects (based on studies with laboratory tested mussels) may be particularly profound (Fuller 1974, pp. 215-273). Factors such as persistence in the environment, metabolism, interaction with other substances, physiologic variations such as those associated with age, environmental temperature, nutritional status, and other factors can affect the toxicity of pesticides (Zinkl *et al*. 1991, pp. 234-255). However, there is currently no available information on the sensitivity of this species to common pesticides. Nonetheless, chemical run-off or spills have resulted in mussel mortalities in various regions of the country (Fleming *et al*. 1995, pp. 877-879), and we believe that the Neosho mucket would be similarly susceptible to pesticide residues (Kansas Department of Health and Environment 1995, pp. 11 and 19).

Metal mining (lead, cadmium, and zinc) in the Tri-state area (5,800 mi^2 (9334 $km^{2)}$ in KS, MO, OK) has impacted lower Shoal Creek and Spring Rivers and been implicated in the loss of Neosho mucket from these sections of the stream (Obermeyer *et al*. 1997b, p. 114). The low pH commonly associated with mine runoff can reduce glochidial encystment rates (Huebner and Pynnönen 1992, pp. 2348-2355). Acid mine runoff may thus impact mussel recruitment. Sedimentation runoff from mines may clog interstitial spaces (Branson and Batch 1972, pp. 507-518), habitat critical for juvenile mussels. A recent study by Kansas Department of Health and Environment documented strong negative correlation between the distribution and abundance of native mussels, including Neosho mucket, and sediment concentrations of lead, zinc and cadmium in the Spring River system (Angelo *et al.* 2007, pp. 477-493).

Metal toxicity continues to be a widespread problem in the Tri-State Mining District (Kansas, Missouri, and Oklahoma). U.S. Environmental Protection Agency 2006 sediment and water quality samples exceeded threshold effect concentrations for cadmium, lead, and zinc at numerous sampling locations within the Tri-State Mining District, which overlaps a large portion of the historic and current range of the Neosho mucket (J. Gunter 2007, pers. comm.). Angelo *et al.* (2007, pp. 485-491) discuss the residual effects of cadmium, lead, and zinc in the Spring River basin from mining activities. Their findings indicated that several mussel species had begun to repopulate the more heavily contaminated segments of the Spring River. However, other mining-impacted streams in the Spring River basin have shown little sign of mussel recovery. U.S. Geological Survey is currently determining sensitivity of Ozark mussels to lead, zinc, and cadmium (C. Ingersoll 2008, pers. comm.).

In-stream and floodplain sand and gravel mining has been shown to cause channel degradation and is associated with mussel declines and extirpations in a number of river basins (Brim-Box and Mossa 1999, pp. 103-104). Sand and gravel mining operations exist within the historic range of the species, and it is likely that other operations will be initiated in the future as the demand for gravel for roads and construction-related activities increases. Since Neosho muckets inhabit streams that are vulnerable to mining activities, it is expected that this particular threat to Neosho mucket habitat will increase.

In summary, the loss of habitat is a significant threat to the Neosho mucket. Severe degradation from channel instability, sedimentation and contaminants threatens the water and habitat quality essential to survival of the Neosho mucket. Sediment from unpaved roads, natural resource extraction, past and current agriculture practices, silviculture, and construction sites can cause both lethal and sub-lethal effects to Neosho mucket populations. Modification of river hydrology and geomorphology associated with rapid urbanization and clearing of riparian areas exacerbated by flood events in 2008 threatens to extirpate in the foreseeable future the once large, viable population of Neosho mucket in the Illinois River, Arkansas. Contaminants associated with industrial and municipal effluents (heavy metals, ammonia, chlorine, numerous organic compounds) and agricultural practices may cause decreased oxygen, increased acidity, and other water chemistry changes that are lethal to mussels, particularly the highly sensitive early life stages of mussels. Furthermore, these threats faced by the Neosho mucket from sources of channel instability, sedimentation, and contaminants are imminent; the result of ongoing projects that are expected to continue indefinitely, therefore, perpetuating these impacts. As a result of the imminence of these threats combined with the vulnerability of the remaining small populations to extirpation from natural and manmade threats, we have determined that the present or threatened destruction, modification, or curtailment of the Neosho mucket habitat and range represents a significant threat of high magnitude.

B. Overutilization for commercial, recreational, scientific, or educational purposes.

The Neosho mucket was once valuable in the pearl button industry, and historic episodes of over-harvest in the Neosho River may have contributed to its decline (Obermeyer *et al*. 1997b, p. 115). Commercial harvest of the species is now prohibited in Arkansas, Kansas, and Oklahoma. Missouri prohibits commercial mussel harvest by default because the species does not occur in commercial waters, but allows up to five Neosho mucket specimens per person per day to be collected for private purposes (*e.g*., bait, shell collection, etc.). Overall, the Neosho mucket's limited distribution and small population size makes it vulnerable to potential illegal commercial harvest or chance collecting by unknowing individuals for personal use.

In summary, over collection of this species would be limited to Missouri and then only for private purposes. Overall, this threat to Neosho mucket is nonimminent and of low to moderate magnitude.

C. Disease or predation.

Diseases of freshwater mussels are poorly known and are unknown as a factor in the decline of the Neosho mucket. Juvenile and adult mussels are prey for a few vertebrate species, including raccoons, muskrats, minks, and freshwater drum. Recently, predation of Neosho mucket by reintroduced otters has been documented in the Spring River in Cherokee County, Kansas (Barnhart 2003, pp. 16-17), and likely occurs elsewhere. Escape of the non-native black carp, a molluscivore currently grown and used for mollusk control in fish farm operations, could present a threat of increased predation to native mollusks, including the Neosho mucket, but it is not known whether or not this species is being used by fish farmers within the range of the Neosho mucket.

The larval stages of trematodes of the family Bucephalidae cause sterilization of native mussels by entering the gonad and allocating the host's resources to asexual reproduction of larval trematodes. About 6 percent of Neosho mucket specimens examined in the Spring River and Shoal Creek were affected by these trematodes (Shiver 2002, p. 13).

In addition to predation by native species, laboratory results from Yeager *et al.* (1999, p. 255) provide evidence that the introduced Asian clam, *Corbicula fluminea*, may prey on newly metamorphosed juvenile mussels. The continued proliferation of Asian clam populations may exacerbate chronic declines in mussel populations in many streams (Yeager *et al*. 1999, p. 257). While predation by naturally occurring predators is a normal aspect of the population dynamics of a healthy mussel population, populations that are already impacted by other factors may be particularly vulnerable to predation. Predation by nonnative species is an additional threat to the Neosho mucket.

In summary, diseases of freshwater mussels remain largely unstudied and are not considered a current threat. Predation is ongoing, and therefore an imminent threat due to the limited population size of the Neosho mucket in extant streams and is expected to continue and remain a threat as long as low populations persist; therefore predation is a threat of low magnitude.

D. <u>The inadequacy of existing regulatory mechanisms</u>.

It appears that existing water quality standards may be inefficient at protecting mussels based on testing of less sensitive species. Although the negative effects of point source discharges on aquatic communities within the range of the Neosho mucket have been moderated by compliance with state and federal water quality regulations, there has been less success in dealing with impacts from non-point source pollution. Human population growth in the upper Arkansas basin threatens further degradation of water quality. The Illinois River watershed in Arkansas occurs in Benton and Washington Counties. Benton County experienced a population increase of 57 percent from 1990 – 2000 and 28 percent from 2000 – 2006; while Washington County experienced an increase of 28 and 17 percent, respectively, for the same periods (U.S. Census Bureau, www.factfinder.census.gov).

Non-point source pollution results from individual private landowner activities (*i.e*., construction, grazing, agriculture, silviculture, etc.) and public construction works (*i.e*., bridge and highway construction and maintenance, etc.). Each state within the range of the Neosho mucket has a variety of laws and guidelines (*i.e*., forestry best management practices) which are intended to minimize nonpoint sources, however, the efficiency at which these regulations work can vary depending on the strength of the regulation, enforcement capabilities, and other factors. Often the inadequacy of these regulations or their enforcement can lead to stream impacts which may affect the Neosho mucket.

The Neosho mucket is protected under Kansas and Oklahoma state laws as an endangered species. The Illinois River in Oklahoma is a state-designated mussel sanctuary, and no mussel harvest is allowed. The species is not protected in Arkansas and Missouri beyond general mussel harvest laws. There is currently no requirement within the scope of federal environmental laws to specifically consider the Neosho mucket during federal activities, or ensure that federal projects will not jeopardize its continued existence.

In summary, existing regulatory mechanisms enforced by the state provide little direct protection of Neosho mucket. Non-point source pollution is not regulated and the Clean Water Act does not adequately protect the habitat from degradation caused by point source pollutants. Municipal wastewater treatment plants discharge large quantities of effluent into rivers or their tributaries within the Neosho mucket range. These are long term projects that are expected to continue indefinitely. Because of the vulnerability of the remaining populations of the Neosho mucket and the imminence of these threats, we find the inadequacy of existing regulatory mechanisms a significant threat of high magnitude.

E. <u>Other natural or manmade factors affecting its continued existence</u>.

Each of the four drainage populations is isolated from the others by one or more major impoundments and by extended reaches of degraded river habitat. The four extant drainage populations are vulnerable to random catastrophic events (*e.g*., flood scour, drought, toxic spills, etc.). During the 2000 drought, the Fall River population of Neosho mucket was severely stressed and threatened by low flow conditions and low dissolved oxygen concentrations (B. Obermeyer 2008, pers. comm.). These isolated populations are vulnerable to land use changes that would result in increases in nonpoint source pollution impacts within occupied watersheds. Isolation also prevents emigration or immigration between populations in response to adverse or positive environmental changes. Due to small population size and resultant reduction of the reservoir of genetic diversity within populations, care should be taken to maximize genetic heterogeneity to avoid inbreeding depression (Templeton and Read 1984, p. 196) and outbreeding depression (Avise and Hamrick 1996, p. 465) whenever feasible in translocation and propagation efforts.

Recent collections indicate Neosho mucket recruitment is limited except in the Verdigris River, Kansas (Mather 1990, pp. 7-13; Harris 1998, p. 5; Obermeyer *et al*. 1997a, pp. 112-113; Vaughn 1997, p. 8). All extant populations of the Neosho mucket are currently dominated by older aged cohorts, and juveniles are rare. Factors limiting recruitment (*e.g*., abundance of black bass, physical and biological requirements for juveniles, etc.) are unknown. It is currently unknown if recruitment rates offset mortality rates in any population.

Exotic species such as the introduced zebra mussel (*Dreissena polymorpha*) and Asian clam compete for resources (space and food) with the Neosho mucket. The zebra mussel has been present in the Arkansas River system for several years and was recently found in northeast Oklahoma in Grand Lake O' the Cherokee (D. Martinez 2008, pers. comm.). Continued dispersal of *Dreissena* into the upper Arkansas system threatens native mussels including the Neosho mucket. Zebra mussels compete with native mussels for food and cause mechanical interference by attaching to the shells of native mussels. Asian clams occur throughout the Neosho mucket range. Zebra mussels have been present in the Arkansas River system since the early 1990's. The zebra mussel currently (2005) is present in the Verdigris River and Grand Lake O' The Cherokee in Oklahoma, and Cheney and El Dorado Lakes in Kansas.

Global Climate Change

While it is likely that the observed increase in global average temperatures is due to the observed increase in human-induced greenhouse gas concentrations, the best scientific data available today does not allow us to draw a causal connection between specific greenhouse gas emissions and effects posed to the Neosho mucket, nor is there sufficient data to establish that such effects are reasonably certain to occur.

Global climate change poses a new potential threat to the Neosho mucket. Current climate change predictions for the Midwest indicate warmer air temperatures, more intense precipitation events, and increased summer drying [U.S. Global Change Research Program (GCRP) 2009]. These changes are likely to have complex and unpredictable effects upon freshwater biota, but some potential effects related to extreme low and high water events and overall temperature changes to mussel populations are intuitive. Increased occurrence of both major flood events and drought in the Midwest would likely affect remaining populations of the Neosho mucket. Additionally, the human response to drought would be increased water withdraw from streams for crop irrigation, and thus, would further decrease water levels in streams intensifying the effects of drought.

Water temperatures would increase in Midwestern streams with the predicted increases in air temperatures (GCRP 2009). More periods of drought would intensify this effect within streams and smaller streams in particular. Because freshwater mussels are ectotherms (body temperature depends on the environment), their physiological processes and reproductive success are constrained and controlled by water temperature. Mussels appear to have varying temperature optima, which strongly influences filtration rates, excretion rates and other processes (Sponner and Vaughn 2008). Therefore, increased water temperatures would be expected to cause changes in the distribution and abundance of species and local extirpations could occur. Species would be expected to respond differently to climate change, and therefore, it is uncertain whether changes in water temperature would affect the Neosho mucket.

Ficke *et al.* (2005) described the general potential effects of climate change on freshwater fish populations world-wide. Overall, the distribution of fish species is expected to change including range shifts and local extirpations. Because freshwater mussels are entirely dependent upon a fish host for successful reproduction and dispersal, any changes in local fish populations would also affect freshwater mussel populations. Therefore, mussel populations will reflect local extirpations or decreases in abundance of fish species. Species such as the Neosho mucket that rely on suitable fish host species also may be affected with changes in the fish community.

As the climate may change, species across the United States are expected to undergo large shifts in range (GCRP 2009). With increases in air temperature, the range of some species may gradually shift northward to stay within their optimal temperature. However, species like the Neosho mucket, with limited and highly fragmented suitable habitat and populations, may have a more difficult time adjusting their ranges or may not be able to respond to changing conditions at all. All streams within the range of the Neosho mucket flow south from rivers in Arkansas, Kansas, Missouri and Oklahoma that eventually flow into the Arkansas River. Given this drainage pattern, a gradual shift in the range of the species northward to a cooler climate would not be possible for the species.

Summary

In summary, a variety of natural and manmade factors historically or currently threatens, or has the potential to threaten, the Neosho mucket. The continued existence of this species is threatened by lack of recruitment and genetic isolation. Non-indigenous species, such as zebra mussel and Asian clam, have potentially adversely impacted populations of the Neosho mucket and its host fish, thereby affecting recruitment, and may directly impact the Neosho mucket through competition for resources. It is currently not possible to remove non-indigenous species. These are self sustaining populations that are expected to persist as a threat indefinitely.

Therefore, we have determined that other natural and manmade factors such as lack of recruitment, combined with and exacerbated by invasive species, pose an imminent threat to the remaining marginal and small populations of the Neosho mucket. The magnitude of these threats is considered high because they severely affect the reproductive capacity of this species and/or cause direct mortality.

CONSERVATION MEASURES PLANNED OR IMPLEMENTED

The *Conservation Strategy for the Neosho Mucket* was developed by the Neosho Mucket Working Group, which consist of nine of our conservations partners and the Service. The purpose of this conservation strategy is to outline a plan to protect the existing Neosho mucket populations and to restore and/or enhance suitable habitat within the species historic range for possible reintroduction. The strategy outlines conservation goals and actions that are offered as guidance to provide a Neosho mucket conservation perspective and help various organizations identify the types of conservation actions that could be implemented to assist in the recovery of the Neosho mucket while benefiting the regional mussel fauna as a whole. The Neosho mucket will be considered secure when each drainage has a viable metapopulation that consists of three distinct cohorts (one of which has reproduced in the past five years), the habitat is fully protected, and viable population levels are maintained for a period of 20 years.

Kansas Department of Wildlife and Parks designated the following occupied and unoccupied (lacking recent documentation) stream reaches critical habitat, which affords the species similar protection to that of the federal ESA (Obermeyer 2000, p. 10):

Neosho River: from the Morris-Lyon county line to the maximum elevation of John Redmond Lake (near Neosho Rapids) and from John Redmond Dam to the Kansas-Oklahoma state line.

Spring River: from where the Spring River first enters Kansas to the backwater of Empire Lake (Cherokee Co.) and from Empire Lake Dam to the Kansas-Oklahoma state line.

Fall River: from the confluence of Spring Creek (south of Eureka) to Fall River Lake (Greenwood Co.) and from Fall River Lake Dam to its confluence with the Verdigris River (Wilson Co.).

Verdigris River: from Virgil to the confluence of West Creek (Greenwood Co.); from Toronto Lake dam to the city of Independence (Montgomery Co.); from the city of Coffeyville (Montgomery Co.) to the Kansas-Oklahoma state line.

Cottonwood River: from Elmdale (Chase County) to its confluence with the Neosho River (Lyon Co.).

South Fork Cottonwood River: from Bazaar to its confluence with the Cottonwood River.

Shoal Creek: from Kansas-Missouri state line to Empire Lake (Cherokee Co.).

Big Caney River: from US 166 (Chautauqua Co.) to the Kansas-Oklahoma state line.

Elk River: from Elks Falls (Elk Co.) to the Elk-Montgomery county line.

Methods have been devised and implemented for the artificial propagation of Neosho muckets (Barnhart 2000, p. 2). Beginning in 1999, 1-2 week old juvenile mussels were released at several sites in the Fall and Verdigris Rivers in Kansas, Shoal Creek in Missouri, and the Spring River in Missouri and Kansas. Shells and live individuals have been recovered from several release sites in the Fall and Verdigris Rivers over the past four years. These animals are identified as recaptures because they are the only juvenile Neosho mucket observed at these sites in over 10 years and match the expected age of the propagated juveniles. During the summer of 2003, quantitative sampling in a reach of the Verdigris River that was seeded in summer 2000 indicated a population density of approximately 75 individuals per 1,000 square meters (Barnhart 2003a, p.8; 2003b, p.ii).

One-week old juveniles have been released in the Fall River (32,150 juveniles), Verdigris River in Kansas (88,900 juveniles), Shoal Creek in Missouri (142,400 juveniles), and Spring River in Kansas and Missouri (1,072,110 juveniles) between 1999 to 2004 (C. Barnhart 2005, pers. comm.). The Service, Missouri State University, and Peoria Tribe reintroduced approximately 200,000 Neosho mucket juveniles to 2 sites in the Spring River under tribal jurisdiction in 2007 (S. Faiman 2008, pers. comm.). Gravid female Neosho mucket individuals were collected from Highway yy in the Spring River, Cherokee County, Kansas, in August, 2008, for propagation and augmentation efforts. Of the juveniles produced, approximately 9,300 were released into the Spring River near Highway 96 at Carthage, Missouri; approximately 9,300 juveniles were released into Shoal Creek near Joplin, Missouri, at Highway 86; and approximately 70,000 juveniles were retained at Missouri State University for grow-out experimentation (S. Faiman 2009, pers. comm.). Local stream team and community watershed groups continue to monitor water quality and other activities in some of the watersheds (i.e., Illinois River, Spring River). A new Audubon Wildcat Glades Nature Center near Joplin, Missouri, is attempting to reach and educate the community about these unique ecosystems, the value of protecting them, and inhabitants such as the Neosho mucket (S. Faiman 2008, pers. comm.).

A graduate student at Oklahoma State University is revisiting Neosho mucket sites surveyed by Vaughn (1997). Preliminary results substantiate the extirpation of this species from the Verdigris and Caney Rivers, Oklahoma.

The U.S. Geological Survey Columbia Environmental Research Center is currently conducting research to assess the sensitivity of mussels inhabiting the Ozarks to acute and chronic effects of lead, zinc, and cadmium in water and sediment exposures. Neosho mucket is a test organism in this research effort (C. Ingersoll 2008, pers. comm.).

The State of Arkansas Illinois River Watershed Conservation Reserve Enhancement Program (CREP) is a partnership between U.S.D.A. Natural Resources Conservation Service and the State of Arkansas. The program seeks to enroll 15,000 acres of eligible marginal pastureland and cropland in 15 year contracts within the Illinois River watershed. The project will establish or restore riparian forest buffers and wildlife habitat buffers by planting native grasses, forbs, trees, and shrubs. This CREP project area includes parts of Benton and Washington Counties. The primary goals of the project are to enhance wildlife habitat and improve water in the Illinois River Watershed.

A diverse group of Northwest Arkansas leaders organized an Upper Illinois River Summit in September, 2005, with 65 watershed stakeholders committing to personal action and agreeing that public education is the number one priority to improve and protect water quality in the Illinois River. In December 2005, the summit group officially formed the Illinois River Watershed Partnership. The Illinois River Watershed Partnership is a membership-based organization working to protect and restore the Illinois River and its tributaries. The organization is working together to improve water quality and to educate and encourage others to enjoy and positively affect the Illinois River Watershed. In 2008 and 2009, the Illinois River Watershed Partnership sponsored The Riparian Project, with volunteers planting thousands of trees along stream banks on tributaries to the Illinois River.

The Neosho mucket is included in the Arkansas, Kansas, Missouri, and Oklahoma State Wildlife Action Plans as a species of conservation concern.

LISTING PRIORITY

THREAT			
Magnitude	Immediacy	Taxonomy	Priority
High	**Imminent**	Monotypic genus	1
		Species	**2***
		Subspecies/population	3
	Non-imminent	Monotypic genus	4
		Species	5
		Subspecies/population	6
Moderate to Low	Imminent	Monotypic genus	7
		Species	8
		Subspecies/population	9
	Non-imminent	Monotypic genus	10
		Species	11
		Subspecies/population	12

RATIONALE FOR LISTING PRIORITY NUMBER

Magnitude:
The Neosho mucket has been extirpated from approximately 62 percent (835 river miles) of its range and very low or no recruitment is occurring in all of the extant populations. Most of this extirpation has occurred in Kansas and Oklahoma. Significant portions of the historic range have been inundated by the construction of at least 11 dams. Channel instability downstream of these dams has further reduced suitable habitat and mussel distribution. There is currently an unauthorized and unfunded proposal to construct a reservoir on Shoal Creek, Missouri, that would further reduce suitable habitat and extant populations. Rapid development and urbanization in the Illinois River watershed will likely continue to increase channel instability, sedimentation and eutrophication to this river. The rapid loss between 2005 to 2008 of entire mussel beds in the Arkansas portion of the Illinois River and decline in distribution and abundance of Neosho mucket threatens to extirpate the species from approximately 30 river miles in the very near future. The Illinois River once represented one of the two viable populations, but continued viability of this stream population is doubtful. The remaining extant populations are vulnerable to random catastrophic events (e.g. flood scour, drought, toxic spills), land use changes within the limited range, and genetic isolation and the deleterious effects of inbreeding. The threats are high in magnitude as they occur throughout the range of this species

and in rivers with the largest populations severely limiting the reproductive capacity and in some cases may cause direct mortality.

Imminence:
The restricted range of the Neosho mucket has led to this species being intrinsically vulnerable to potential threats, such as those mentioned below. Populations that were once stable and viable in the Illinois River have experienced significant declines since 2005 due to rapid urbanization and development and clearing of forested riparian habitat within the watershed. The Spring River supports the only locally abundant and viable Neosho mucket population. While some threats are not imminent, the majority of them are ongoing and thus imminent.

There are non-imminent and imminent threats to this species. Imminent threats include: (1) sedimentation caused by channel instability, mining, and undesirable land management practices, (2) deterioration of habitat quality and loss of habitat due to channel aggradation and migration associated with urban development and undesirable land use management practices in Northwest Arkansas, (3) Joplin wastewater treatment plant effluent to Spring Creek, (4) unrestricted cattle access at levels that degrade water quality and habitat, (5) historical and current metal mining operations, (6) zebra mussels where invasions have occurred, (7) Asian clam competition range wide, (8) existing gravel and sand mining operations, (9) eutrophication in urbanized areas and stream segments with a dominance of agricultural uses, (10) proposed reservoir on Shoal Creek, (11) expansion of zebra mussel into uninfested stream reaches, (12) predation from raccoons, muskrats, etc., and (13) inadequacy of existing regulatory mechanisms.

Non-imminent threats include: (1) habitat reduction and degradation resulting from reservoir construction, (2) contaminants from various sources, (3) new gravel and sand mining operations, (4) overutilization for bait or scientific purposes, (5) parasites, and (6) random catastrophic events.

Rational for Change in Listing Priority Number: Not applicable.

Yes Have you promptly reviewed all of the information received regarding the species for the purpose of determining whether emergency listing is needed?

> Is emergency listing warranted? No. We have evaluated the current immediacy and magnitude of identified threats to this species in the threats analysis section of this form. At this time, we do not believe this species warrants the need for emergency listing as outlined in Section 4 of the Endangered Species Act. However, we will continue to monitor and assess the status and trends of the species and could adjust this conclusion based on the best scientific and commercial information available.

DESCRIPTION OF MONITORING
Extensive coordination with state environmental agencies has been conducted during the past decade to determine the range of and threats to the Neosho mucket. In 1994 and 1995, Service personnel representing Kansas, Missouri, Arkansas, and Oklahoma met to discuss priority issues with regard to candidate and unlisted species. Neosho mucket was identified at both meetings as the top priority species shared among the four states, and updated status survey work was identified as the primary need. Survey work encompassing the entire range of the species has been completed in all four states. The Missouri Department of Conservation, Kansas Department of Wildlife and Parks, Service, and Missouri State University are working to

artificially propagate Neosho mucket for population augmentation and reintroduction. The Kansas Department of Wildlife and Parks have developed a State recovery plan and designated critical habitat for the Neosho mucket and three other rare mussel species.

The Neosho Mucket Working Group, which is comprised of four Service Ecological Services field offices, one National Fish Hatchery, three TNC field offices, five state agencies, U. S. EPA, and three universities, meets annually to discuss the current status, distribution, and conservation efforts for the Neosho mucket. The group completed a conservation strategy for the species in 2005. During the preparation of this document, the group reviewed and updated all information on distribution, status, threats, and conservation goals and actions needed to recover the species. The Service, U.S.D.A. Forest Service, and Arkansas Game and Fish Commission conducted a status survey in the Arkansas portion of the Illinois River in 2008 and subsequent monitoring is planned at 3 – 5 year intervals or as needed.

COORDINATION WITH STATES

An e-mail was sent to the Neosho Mucket Working Group on February 24, 2010, requesting new information on the Neosho mucket status. The following individuals provided comments:

- Edwin Miller (Kansas Department of Wildlife and Parks) – provided a summary of 2009 Neosho mucket sampling in the Verdigris River, Kansas.
- Stephen McMurray (Missouri Department of Conservation) – provided all records of Neosho mucket in the MDC database.

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Threats Assessment Matrix

Stressors/ Populations	Illinois River	Spring River	North Fork Spring R.	Verdigris River	Fall River	Elk River, MO	Neosho River	Shoal Creek
Impoundment Magnitude: Immediacy:	 Mod - Low Non-imminent	 Mod - Low Non-imminent	 NA NA	 Mod - Low Non-imminent	 Mod - Low Non-imminent	 Mod - Low Non-imminent	 Mod - Low Non-imminent	 High Imminent
Sedimentation Magnitude: Immediacy:	 High Imminent	 Mod - Low Imminent	 Mod - Low Imminent	 High Imminent	 Mod - Low Imminent	 Mod - Low Imminent	 High Imminent	 Mod - Low Imminent
Nutrients Magnitude: Immediacy:	 High Imminent	 High Imminent	 High Imminent	 Mod - Low Imminent	 Mod - Low Non-imminent	 High Imminent	 Mod - Low Imminent	 High Imminent
Pb & Zn Mining Magnitude: Immediacy:	 NA NA	 High Imminent	 Mod - Low Imminent	 NA NA	 NA NA	 NA NA	 High Imminent	 High Imminent
Pesticides Magnitude: Immediacy:	 Mod - Low Non-imminent	 Mod - Low Non-imminent	 Mod - Low Non-imminent	 Mod - Low Non-imminent	 Mod - Low Non-imminent	 Mod - Low Non-imminent	 Mod - Low Non-imminent	 Mod - Low Non-imminent
Channel Instability Magnitude: Immediacy:	 High Imminent	 High Imminent	 High Imminent	 High Imminent	 High Imminent	 Mod-Low Non-imminent	 High Imminent	 High Imminent
Overutilization Magnitude: Immediacy:	 Mod - Low Non-imminent	 Mod - Low Non-imminent	 Mod - Low Non-imminent	 Mod - Low Non-imminent	 Mod - Low Non-imminent	 Mod - Low Non-imminent	 Mod - Low Non-imminent	 Mod - Low Non-imminent
Predation Magnitude: Immediacy:	 Mod - Low Imminent	 Mod - Low Imminent	 Mod - Low Imminent	 Mod - Low Imminent	 Mod - Low Imminent	 Mod - Low Imminent	 Mod - Low Imminent	 Mod - Low Imminent
Exotic Species Magnitude: Immediacy:	 Moderate Imminent	 Mod - Low Imminent	 Mod - Low Imminent	 Mod - Low Imminent	 Mod - Low Imminent	 Mod-Low Imminent	 Moderate Imminent	 High Imminent
Sum of Stresses Magnitude: Immediacy:	 High Imminent	 High Imminent	 Mod – Low Non-imminent	 Moderate Imminent	 Mod - Low Non-imminent	 Mod-Low Imminent	 Moderate Imminent	 High Imminent

APPROVAL/CONCURRENCE: Lead Regions must obtain written concurrence from all other Regions within the range of the species before recommending changes, including elevations or removals from candidate status and listing priority changes; the Regional Director must approve all such recommendations. The Director must concur on all resubmitted 12-month petition findings, additions or removal of species from candidate status, and listing priority changes.

Approve: Janet Mizzi

______________________________________ June 15, 2010_
for Regional Director, Fish and Wildlife Service Date

Concur: Rowan W. Gould
ACTING
Director, Fish and Wildlife Service Date: October 22, 2010

Do not concur:________________________________ __________
Director, Fish and Wildlife Service Date

Date of annual review: March 12, 2010

Conducted by: Chris Davidson - Conway, Arkansas FO